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Psychometrische Untersuchungen. JAMES McKEEN CATTELL. Inaug. Dis. Wundt's Philos. Studien, III (1866), pp. 452-492; *Mind*, XI (1886), pp. 220-242, 377-392, and 524-538.

(2.) *Wundt's Philos. Studien*, IV (1887), pp. 241-250. *Mind*, XII (1887), pp. 68-74.

In his discussion of the factors of reaction times, Dr. Cattell more than foreshadows the distinction of sensory and motor reactions, which Wundt has made so important in the last edition of his *Psychology*. He conceives that in the reactions of practiced subjects the brain processes are not chiefly those that attend perceiving and willing, but rather a kind of voluntarily prepared reflex. "That is," he says, in speaking of light reactions, "the subject by a voluntary effort . . . puts the lines of communication between the centre for simple light sensations (in the optic thalami, probably), and the centre for the co-ordination of motions (in the corpora striata, perhaps connected with the cerebellum), as well as the latter centre, in a state of unstable equilibrium." In case, then, of an incoming nervous excitation, a part goes on to the cortex and arouses consciousness, but a part also shoots off on the prepared lines and causes the immediate execution of the motion of reaction. Dr. Cattell generally used his gravity chronometer, (*vide* §2, p. 709, Vol. I of this JOURNAL), to control the giving of the stimulus. For the signaling of the reaction he used a telegraph key, a lip key, and a sound key. The signal was made with the first by raising the finger, and in the others by calling out. The time was measured by a Hipp chronoscope. The author and Dr. G. O. Berger, both somewhat experienced in psychological experiment, acted as subjects, and care was taken not to introduce irregularity by fatigue, etc. The simple reaction time for daylight reflected from white paper was found to be for B. 0.151 s., for C. 0.147 s., reactions with either hand being about equally quick, with the vocal organs about 0.030 s. slower.

The central stages of reaction time, *i. e.* perception time (*Unterscheidungszeit*) and will time (*Wahlzeit*), cannot be measured directly; the only safe way to study them is in their variations. If the manner of reacting remains the same, the will time should be nearly constant, and the independent variations of perception time open to study. In the first set of experiments on perception time, the subject was shown two cards, one black and the other white on a black background, and was required to react with the hand to the white alone. This gave, B. 0.207 s., C. 0.242 s. Subtracting from these the simple reaction time, on the assumption (which, however, the author makes with some hesitation) that all the processes of conduction, etc., are the same, there is left for the stages of perception and will, for B. 0.061 s., for C. 0.095 s., and dividing these equally between them (which cannot lead to gross error with such small numbers), gives for the simple perception time alone B. 0.030 s., C. 0.050 s. Calculation from the vocal reactions gives about the same results. Variations of the experiments by the substitution of colors or letters or words as stimuli, and by changes in the discriminations to be made, increased the perception time by different amounts. The perception time for pictures about one cm. square and, as the author conjectures, for the objects to which they correspond, was for B. 0.092 s., for C. 0.117 s.

The will time is studied by changing the manner of reacting. Instead of reacting to a designated stimulus in a single fixed way,

stimuli of several kinds are used and a different reaction set apart for each. If two stimuli are used, reaction may be made to one with the right hand, to the other with the left. Using red and blue and yellow and green as such pairs of stimuli, B. took 0.018 and C. 0.034 longer than when a single previously determined motion sufficed. Such experiments were also made on letters with similar results, but the most numerous were made with vocal reactions—the color was named, the word called out, etc. In this case the variations in the manner of reacting are more numerous and the association of stimulus and reaction closer. Letters, figures, colors, words, and pictures were the stimuli, and interesting variations in their times were discovered.

Dr. Cattell sums up his measurements in round numbers, in thousandths of a second, as follows: Simple reaction time for light, B. 150, C. 150; recognition time for light, B. 30, C. 50; for a color, B. 90, C. 100; for a picture, B. 100, C. 110; for a letter, B. 120, C. 120; for a short word, B. 120, C. 130; naming time for colors, B. 280; C. 400; for pictures, B. 250, C. 280; for letters, B. 140, C. 170; for words, B. 100, C. 110. The author investigated with great care, as well, the effect of attention (concentrated, normal, and distracted), fatigue (making a very long special test), and practice, concluding that the first two are of less influence, at least with practiced observers, than has commonly been supposed.

(2) The last division of this research carries still further the application of time measurements to mental action. Four of the five groups of measurements deal with association or recollection, the fifth with the time of acts involving a judgment. The first group gave the time for naming pictured objects in a foreign language (for B. 0.172 s., for C. 0.149 s. longer than to do the same in the mother tongue), and for translating German words into English and *vice versa* (from less than one-fifth to nearly three-fifths of a second longer than for simply seeing and naming a word). For the second group the subject was required to give the country when a well-known city was given, the sum or product of given numbers, the language when an author was given, etc. These associations required from two-fifths to four-fifths of a second. The third group allowed more liberty of answer. When a country was given, the subject had to reply by a city in it, or when an author was given, by one of his works, etc. The times ranged from about two-fifths to one and one-tenth seconds. The associations of the fourth group were such as a thing with its parts or its uses, class name with examples of the class, a verb with subject or object, etc. The time required was from a little under three-tenths to a little over four-fifths of a second. The element of judgment was introduced in the fifth class by requiring an estimate of the length of single lines, or of the number in groups of them, or the relative greatness of great men. The times were from about one-sixth to about one and one-eighth seconds. For the exact figures, as for interesting peculiarities of association suggested by them, the article itself must be consulted. The mental processes measured, however, are not the same even in groups of the same general form; the average variations of the times found are very large, amounting in the corrected averages not infrequently to more than one-fifth of the whole; and the number of experiments is very small, often not more than twenty-six of a kind. These points, which the author indeed recognizes, leave this part of his research with hardly any

value more weighty than suggestiveness. It may very well be questioned whether the measurements have not been pushed to more complicated processes than can yet be approached with advantage.

E. C. S.

Ueber den Einfluss der Uebung auf geistige Vorgänge. Dr. G. O. BERGER.
Wundt's Philos. Stud. V. 1. 1888.

The influence of practice was measured by its effect on the rapidity with which gymnasium pupils of different classes, and those of the highest class of a preparatory school, could pronounce Latin and German. The best five and the worst five in each of the classes were taken for the trial; the average age in the class from the preparatory school was 9; in the highest gymnasium class, 21.6. The test consisted in reading with the greatest rapidity first 100, then 500 words, and third, the first 100 words again at the normal rate. The Latin read was from Tacitus's *Agricola*; the German, from Goethe's *Egmont*. The improvement in the rate through the ten classes follows what may be assumed as the general law of the effect of practice, namely, a rather rapid quickening at first, followed by less and less gain as practice continues. The time for 100 words in the preparatory class, which had not as yet studied Latin, was 262 seconds; for the gymnasium classes respectively, 135, 100, 84, 79, 57, 54, 49, 48, 43. For German the times were 72, 55, 43, 37, 39, 28, 27, 26, 25, 23. The 100-word rate in Latin is 7 per cent shorter than that which can be kept up for 500 words; in German, but 3 per cent. The "normal reading" in the lower classes was a little quicker than the first reading because the words were a little familiar. The higher classes took longer for the second reading than for the first because they read for the sense. To set aside the possible objection that the increased speed was an evidence of increased mental quickness, and not the result of familiarity with the language, the gymnasium pupils were shown sets of five and of ten colors, and the time required to recognize and name them measured. The rates do not increase regularly with the increase in age, as they should do if the objection were valid. Granting the increased rapidity by practice, the question follows as to how practice has made the change. The gain appears to be chiefly in the overlapping of processes, as in Cattell's experiments (noted in the *JOURNAL*, I, p. 709), and in the size of the groups of words grasped at a time. The children in the preparatory school, for example, read Latin by syllables; those a little more advanced, by words; the highest, by phrases, as is testified by the kinds of errors made in reading at full speed, and by the less proportionate advantage shown by the boys of the higher classes in reading disconnected words.

Ueber die Reactionszeit für Erregung und für Hemmung. GAD, nach Versuchen des Herrn Dr. Orschansky. Verhandlungen der Physiol. Gesells. zu Berlin, No. 13-14, June 4, 1887.

The muscle selected for these experiments was the masseter, because its relaxation is not attended by the contraction of an antagonist. Its contractions and relaxations, by means of which the reaction times for excitation and inhibition were measured, were recorded by a double-branched apparatus, one branch of which entered the mouth on each side and pressed against the muscle,